

***Vaccines: what they are, how they work, the many different ones, and the myths surrounding
them***

An Honors Thesis (HONR 499)

by

Heather Ashby

Thesis Advisor

Dr. Jennifer Metzler

Ball State University

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Abstract

Vaccines are an important component of healthcare in the world today. Vaccines are able to prevent people from getting many diseases and provide protection for the future. However, many people have concerns over the safety of vaccines and question why they are necessary. Many people are beginning to not have their children vaccinated out of fear for what the vaccine will do, such as cause autism. In this paper I provide the basic immunology information that is important to understand vaccines, the types of vaccines used, information on common vaccines, information on the safety of vaccines, and I address some of the concerns of parents, in particular the fear of autism caused by vaccines.

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Process Analysis Statement

As a biochemistry major I have had the opportunity to take many biology and chemistry classes over the course of my time at Ball State. In the fall of 2016 I took an immunology class that was very interesting to me. This class led to me wanting to conduct my thesis over the topic of vaccines. I am also a pre-pharmacy major and plan to go to pharmacy school to become a pharmacist. The topic of vaccines is pertinent to this area because as a pharmacist I will have to administer vaccines to people and will need to be knowledgeable about vaccines. Researching the history of vaccines and how they work will give me more knowledge and understanding about vaccinations.

The target audience for this thesis will be anyone interested in learning more about the benefits of vaccines, whether they are just curious or they are trying to decide whether or not they should vaccinate their children or be vaccinated themselves. I expect others to learn how vaccines are used and how they have helped to eliminate diseases. I expect them to learn some of the biological functions of vaccines so that they fully understand how vaccinations work. Recently the topic of whether or not parents should vaccinate their children has been a controversial topic and I hope to educate people about the safety of vaccines in this thesis.

I began work on my thesis by outlining what topics I wanted to cover. I know that not everyone fully understands how vaccines work and so I wanted to incorporate that into my thesis. I did not want to get too technical so that anyone, no matter their knowledge background could understand it. I also wanted to discuss the different types of vaccines that are used since this is a major component of educating people about vaccinations. I included some information on many of the common vaccines used so that this thesis could be an inclusive and one stop paper for those wanting to be educated on vaccines. Finally, I thought it was very important to

include a section on the safety of vaccines as this is a major issue for those who do not want to have their children or themselves vaccinated. In the same area of safety I also included some information on the myth that vaccines, the MMR vaccine specifically, causes autism.

Completing this thesis was a daunting task as I have never considered myself to be that great of a writer. I found that setting due dates throughout the semester was very beneficial. However, I also discovered I am not as good at time management as I thought, although this project has definitely allowed me to learn how to be better at it. I did hit a few road blocks when writing this thesis, mostly because I could not find good articles to reference. But I was able to work through the road blocks and produce a complete thesis. I have never written or worked on a project of this caliber and from the beginning I was not sure how I could do it. But now that it is completed it has given me the confidence to know I can do anything as long as I work hard at it and do not give up. Following is a thesis on vaccines that I am very proud to say that I wrote.

What is a vaccine?

Illnesses are a common occurrence in the world today. Every year the flu alone causes many people to be hospitalized and can even lead to death. Since 2010 the CDC estimates that between 140,000 and 710,000 people were hospitalized due to the flu and between 12,000 and 56,000 died due to the flu (Key Facts...2017). However, with the invention of vaccines some diseases and sicknesses are being prevented. To understand vaccines it's important to first discuss the immunology component of them. One must also understand the body and how the immune system fights off diseases and illnesses. Once this is known then vaccines can begin to be understood. There are different types of immunity along with different types of vaccines that are utilized. Vaccines are used to help protect people from diseases and prevent them from getting certain diseases. Vaccines have been created for many diseases and most are administered at young ages. Some of the vaccines that have been created are for smallpox, diphtheria, pertussis, measles, mumps, rubella, and more. Because of vaccines smallpox has been completely eradicated and 99% of polio cases have been reduced (Zepp 2010). However, for the past twenty years concerns have been growing over vaccines and their safety. Some individuals have even begun making the choice to not get vaccinated or to not vaccinate their children, thinking that the vaccines cause other problems, such as autism.

Basic Immunology Components

There are two components to the immune system of the human body, the innate and adaptive immune systems. The innate system works first to ward off pathogens and provides protection against letting pathogens inside the body. If needed the adaptive system comes into

play and provides a stronger defense. The adaptive system involves B and T cells that work inside the body to kill any pathogen that made its way past the innate protection. These systems work together to fight off invading pathogens, bacterium, viruses, or other microorganisms that can cause disease or illness (Dictionary.com).

The innate immune system gives a general defense to pathogens. The responses to the innate immune system are not specific to one pathogen but instead respond to recognized patterns on many pathogens (Clem 2011). The fact that the innate system does not give specific responses means that it cannot retain memory. The components of the innate immune system cannot remember certain pathogens and cannot build up a stronger defense to the same pathogen if encountered again (Clem 2011).

The components of the innate immune system include the skin and mucous membranes (Clem 2011). The skin provides protection because it is very acidic which prevents organisms from growing on it (Clem 2011). The mucous membranes work by helping to capture and expel microorganisms from the body. These membranes are found along the tracts in the body such as the respiratory and digestive tracts, along with lining the mouth, nose, eyelids, trachea, lungs, intestines, and stomach (Encyclopedia Britannica). However, these membranes do not affect the normal microorganisms that are always a part of the body. In fact, the normal microorganisms that reside on the skin and membranes provide some protection by allowing less room for harmful bacteria or organisms to grow. Other components of the innate immune system include the body's temperature, the acidic gastric juices, and lysozymes (Clem 2011). The body's temperature can prevent some organisms from surviving if they typically thrive at a different temperature, whether higher or lower. The juices in the stomach are very acidic which inhibits

many organisms from living. Lysozymes are enzymes in tears and other mucus secretions which can aid in the breakdown of the cell wall on invading pathogens (Clem 2011).

There are also certain responses that occur in the innate immune system that help fight invading organisms. One response of the innate immune system is the inflammatory response which includes fever, redness, swelling, heat, and pain (Clem 2011). This response works to kill the invading pathogen. Another major component of the innate immune system is the complement response which consists of three pathways that come together creating a complex called the membrane attack complex. This complex then constructs pores in the harmful cells that caused the response and leads to the cell's death (Clem 2011). The three pathways of complement also produce anaphylatoxins that are an important component of and enhance the inflammatory response (Sarma J and Ward P 2011). Anaphylatoxins act as chemoattractants in which they attract phagocytes (Sarma J and Ward P 2011), or a cell that can ingest bacteria, foreign particles, and other cells, to the area of inflammation (Phagocyte). They also function as vasodilators, promote contraction of smooth muscle, and induce the release of histamine (Sarma J and Ward P 2011).

Another way the innate immune system works is by using pattern recognition receptors (PRRs). PRRs are membrane proteins that can recognize pathogen associated molecular patterns (PAMPs) on invading pathogens. An important example of a PRR is a toll-like receptor (TLR). There are many TLRs that have been identified and while they each have a specific function, overall they work to recognize the components of invading microbes or pathogens (Takeda K and Akira S 2005). When PRRs recognize PAMPs it triggers activation of complement, release of cytokines, activation of phagocytes, and opsonization (Clem 2011), which is the process by which bacteria and other cells are altered in such a manner that they are more readily and more

efficiently engulfed by phagocytes (Opsonization). Examples of PAMPs that PRRs can recognize are the endotoxin LPS, peptidoglycan, double-stranded DNA in viruses, flagellin, lipoproteins, and hypomethylated DNA (Clem 2011). Together these components of the innate system work to keep microorganisms and pathogens from invading too far. However, when the pathogen or microorganism is able to evade the innate immune system, the adaptive immune system comes into play.

The adaptive immune system is different from the innate in that it responds more specifically to the invading pathogen. The adaptive immune system also has memory capability which means that it can remember specific pathogens and will be able to build up a stronger response when the pathogen is encountered again. However, the adaptive immune response takes longer than the innate immune response. The adaptive immune system consists of B cells and T cells and these cells generate two types of immune responses. B cells are a part of antibody-mediated immunity, also called humoral immunity, and T cells are part of cell-mediated immunity (Clem 2011). Together these cells work to carry out the functions of the adaptive immune system.

B cells are made and mature in the bone marrow and then move to a secondary lymphoid organ which include lymph nodes, spleen, tonsil, or Peyer patches (Clem 2011 and Pieper et al 2013). The job of B cells is to recognize extracellular antigens or toxins. They can be activated by antigens alone through the B-cell receptor or they can be further activated by helper T cells (Pierce 2002). When B cells are activated by antigens alone, the response is not very strong and there is not much memory. Therefore, B cells will typically need additional activation by helper T cells (Pierce 2002). When helper T cells help activate B cells, there is a much stronger immune response and stronger memory (Clem 2011). The recognition of antigens by B cells then causes

the B cell to grow into a plasma cell. The plasma cells then produce antibodies to the specific antigen. Many copies of the activated B cells can then be made and they can become either plasma cells or memory B cells, which stay in the lymph node in case the pathogen is encountered again (Clem 2011).

T cells are made in the bone marrow, move to and mature in the thymus, and then move into the blood (Clem 2011). There are two types of T cells and both of their jobs is to recognize intracellular antigens. The CD4 T cells recognize cells that have the protein called the major histocompatibility complex II protein (Clem 2011). The cells with this protein are immune cells and therefore CD4 T cells interact with immune cells. CD4 T cells are the helper T cells mentioned previously. These cells help activate the B cells and are important for antibody-mediated immunity (Clem 2011). The other type of T cells are the CD8 T cells which are important for cell-mediated immunity. These cells are also called cytotoxic T cells and recognize cells with the major histocompatibility complex I protein. Cells with this complex are all nucleated or professional antigen presenting cells and therefore CD8 T cells act to mark body cells (Clem 2011). T cells are only able to recognize an antigen if it has been processed and then presented by an antigen-presenting cell (Clem 2011). After a T cell is activated, many copies can be made to become either effector T cells that work to fight against invading pathogens or memory T cells that stay in case the pathogen is encountered again.

Passive and Active Immunity

There are two different types of immunity, passive and active. Passive immunity can be natural or acquired immunity and it, “refers to the process of providing IgG antibodies to protect

against infection,” (Baxter 2007). This type of immunity does not last for a long amount of time, usually from a few weeks and up to about 3 months (Baxter 2007). However, its effect is immediate. An example of natural passive immunity is the passing of maternal antibody to the baby across the placenta. To receive acquired passive immunity, serum or immunoglobulin from an immune person is collected, pooled, and the immunoglobulin is concentrated and then injected into the person needing the immunity (Baxter 2007). An example of acquired passive immunity is the use of human hepatitis B immunoglobulin that is given to workers in health care who are exposed to the hepatitis B viruses (Baxter 2007).

Active immunity is when a person is exposed to an antigen in order to stimulate an adaptive immune response (Baxter 2007). This response is not immediate like in passive immunity but instead can take days or weeks. However, unlike passive immunity, the response can last for a long time (Baxter 2007). Since the adaptive immune response is activated in active immunity, the memory capability is also activated. This means memory cells that are made can remember specific pathogens and will be able to respond more strongly when the pathogen is encountered again. Active immunity also can be acquired or natural (Baxter 2007). An example of natural active immunity is becoming infected with the hepatitis A virus but then recovering (Baxter 2007). This provides the person with further protection from becoming infected again. An example of acquired active immunity is instead being given the hepatitis A vaccine. When given two doses of this vaccine a long-lasting immune response is stimulated (Baxter 2007).

Vaccine Types

There are four different types of vaccines and they are classified based on the type of antigen used. The four types are toxoid, subunit, live attenuated, and killed inactivated. Each vaccine type also contains other components in them that can help enhance the immune response, help stabilize the product, are the carrier used for delivery of the vaccine, or is a leftover from the manufacturing process (Baxter 2007). The vaccine type used depends on what infectious disease is trying to be prevented.

Toxoid vaccines are a vaccine used against diseases that are caused by exotoxins. For a toxoid vaccine, a toxoid is created that is very similar to the original toxin and this allows for cross-reacting antibodies (Baxter 2007). The main goal of the toxoid vaccine is to create antibodies against the toxoid that are better able to bind the toxin than are the nerve cells in the body (Baxter 2007). Examples of toxoid vaccines include tetanus, diphtheria, botulism, pertussis, and cholera. Toxoid vaccines are not very immunogenic so many doses need to be used along with an adjuvant (Baxter 2007). The adjuvant helps enhance the immune response to make it more long-lasting so that a large amount of the toxoid does not have to be used (Baxter 2007).

In a subunit vaccine a certain antigen is used or a combination of antigens are used to generate antibodies against a specific component of a pathogen instead of stimulating antibodies against all antigens of the pathogen (Baxter 2007). A subunit vaccine elicits an immune response that differs depending on if the antigen in the vaccine is a protein or a polysaccharide. Examples of a subunit vaccine are Hepatitis B, *Haemophilus influenzae* b, and influenza. Hepatitis B and *Haemophilus influenzae* b use only one antigen while influenza uses two antigens (Baxter 2007). Subunit vaccines are similar to toxoid vaccines in that they also require the use of an adjuvant.

A live attenuated vaccine uses an attenuated form of the pathogen. This means that the pathogen is still capable of replication but is weakened. One method of attenuating the pathogen

is growing it in a foreign host. It then replicates and mutants are formed. The mutants that have a higher virulence in the foreign host are chosen because they typically have a lower virulence in the human host and therefore would work well in the vaccine (Baxter 2007). Another method for attenuation is growing the pathogen in an artificial growth medium at a temperature that is lower than the body's temperature. Given time a strain could appear that can grow at the lower temperature but grows so slowly that in the human host there would be sufficient time for an immune response to take place and kill the pathogen (Baxter 2007). Examples of live attenuated vaccines include measles, mumps, chickenpox, and rubella. A major disadvantage with this type of vaccine however, is the possibility to cause the illness the vaccine is trying to prevent (Baxter 2007). However, this only happens if the pathogen returns to a harmful state or if an individual is immunocompromised and therefore the pathogen cannot be appropriately attenuated (Baxter 2007).

Killed/inactivated vaccines are similar to the toxoid vaccine, however, they stimulate an antibody response against a range of antigens (Baxter 2007). In the name, 'killed' refers to a bacterial vaccine and 'inactivated' refers to a viral vaccine. Killed or inactivated vaccines are produced by using chemicals, heat, or radiation to kill the microbes causing the disease (Types of...2017). The response generated takes about two weeks to occur but a follow-up encounter would activate the memory B cells and induce a much quicker response that would take about one or two days (Baxter 2007). Because the microbes cannot replicate in the host, multiple doses are typically needed along with an adjuvant in the vaccine in order to generate a strong response (Baxter 2007). An example of a killed/inactivated vaccine is the vaccine for hepatitis A.

How does a vaccine work?

What has been described thus far are the basic components of the immune system. This knowledge can be used to understand how a vaccine works. There are two types of immunity, active and passive which were described previously, and therefore two types of vaccines. An active vaccine works to induce the primary immune response. This stimulates B cell proliferation, T cell sensitization, and an antibody response (Bartlett et al 2009). Some of the B cells can then remain as memory B cells. When the memory B cells then later come into contact with an antigen it recognizes from the given vaccine they begin to divide and differentiate quickly (Bartlett et al 2009). They differentiate into plasma cells that secrete antibodies that work to stop or limit an initial infection and work to kill infected cells (Bartlett et al 2009). Antibodies do this by many methods. They can neutralize pathogens by preventing them from attaching, cause pathogens to aggregate, or paralyze pathogens (Forthal 2014). This is what an active vaccine aims to do, introduce an antigen so that the primary response is made. This allows the formation of memory cells that are now present if the pathogen is encountered and a faster secondary response can be mounted. This secondary response ensures protection for the individual against whatever disease for which the vaccine was given. Most vaccinations induce this type of immunity (Bartlett et al 2009). A passive vaccine uses a globulin product and the direct delivery of an antibody to protect against a specific antigen. This kind of vaccine only provides short-lived immunity (Bartlett et al 2009).

Smallpox: the first vaccine

Smallpox is a disease that is caused by the virus variola and is a highly contagious disease. It is spread by droplets, in aerosol form, or by contact with infected sores or clothing (Baltimore R and McMillian J 2002). The virus incubates for a short period of one to two weeks

and then a rash develops on the face and limbs, along with spots on mucus membranes (Baltimore R and McMillian J 2002). The rash and sores are the distinct characteristics of smallpox. There are four different types of smallpox: the standard type, hemorrhagic (variola major), malignant (variola major), and variola minor. Smallpox had a death rate of 30% or greater during epidemics (Baltimore R and McMillian J 2002). This varied however depending on which type of smallpox a person had or how severe the case. However, there has not been a case of smallpox in the world since 1977. This is because of the creation of the smallpox vaccine, the first vaccine to be created.

The smallpox vaccine was initiated by Edward Jenner, an English physician. Before the creation of the smallpox vaccine, there were other methods in place to reduce the spread of smallpox. This method was called variolation or inoculation. Inoculation was conducted by taking "matter" from the sore of someone with smallpox and injecting it subcutaneously into an un-inoculated person (Riedel 2005). This method did not work perfectly though, as people still could spread the disease, and other diseases were contracted via the transmission process. But once a person had smallpox they were immune to it and would not contract it a second time. As a teen, Edward Jenner heard that those who had cowpox were then immune from smallpox. Many years later, after studying many subjects such as biology and medicine, among others, Jenner had the idea of transferring cowpox to be used in protection against smallpox (Riedel 2005). He then tested his theory on an 8 year old boy whom he inoculated with cowpox and later inoculated with smallpox. The boy did not develop cowpox or smallpox. Edward Jenner began to tell his friends and colleagues about his discovery. This was in 1796 but the use of the vaccination did not start spreading in Europe until 1800 (Riedel 2005). It then made its way over to the United States.

Edward Jenner named the process vaccination because the Latin word for cow is vacca and cowpox is vaccinia (Riedel 2005).

Other vaccines

Since the creation of the first vaccine for smallpox, many other vaccines have been produced for a variety of diseases. Most of the vaccines are for diseases that are common in the world and easily prevented. These vaccines have certain rules that go with them that dictate when they should be administered and when they should not be administered. Some information about the diseases and the vaccines that go with them will be provided here but more information can be found on www.cdc.gov/vaccines and www.vaccines.gov. The vaccines covered here are: chickenpox, measles, mumps, rubella, diphtheria, tetanus, pertussis, polio, pneumococcal, and influenza.

Chickenpox

Chickenpox is also known as varicella and is a disease that most people are familiar with as it is a common disease in children. Before the creation of the vaccine there were about 11,000 people hospitalized each year in the United States for the disease and about 100 people died from it each year (Vaccines by... 2016). A chickenpox infection can cause itchiness, rashes, fever, and fatigue. It is usually a mild disease but can become serious and cause other problems such as pneumonia, brain damage, or even death (Vaccines by... 2016). This vaccine works to prevent chickenpox but someone who received the vaccine may still get the disease. However, it will not be a severe case and will most likely be mild. Typically children are the ones who receive the chickenpox vaccine but it can be given to adults. The standard is for children ages 12-15 months to get their first dose followed by a second dose at ages 4-6 years (Vaccines by... 2016). Anyone

over 13 years old can get the doses 28 days apart. Adults who have not proven they are immune should receive the standard two doses of the single antigen varicella vaccine (Adults Schedule 2017). To prove they are immune a laboratory test can be done in order to determine immunity. The test is a titer which determines how many antibodies are present in a person's blood. If the titer shows an adult is immune then they would not need the vaccine (What is a titer?... 2015).

MMR

Some vaccines are combined together in one dose so that only one shot needs to be given. One example of this is the MMR vaccine which includes the measles, mumps, and rubella vaccines. This vaccine can also include the chickenpox vaccine and it is then called MMRV where the V stands for varicella. Children should receive two doses of the MMR vaccine. The first dose should be given between 12 and 15 months of age. The second dose should be given between the ages of 4 and 6 (Diseases and... 2017). Adults can also receive the vaccine if they did not get it as a child.

Measles

The measles disease is caused by a virus and is very contagious. The disease is spread by coughing or sneezing. The symptoms of measles include fever, cough, runny nose, sore throat, and a rash covering the body (Diseases and... 2017). It can also cause an ear infection, diarrhea, pneumonia, damage to the brain, or even death (Diseases and... 2017). The vaccination of measles began in 1963, but before it began about 3 to 4 million people would get measles every year in the United States. There were about 500,000 cases reported to the CDC and of these, 48,000 people were hospitalized, 1,000 people got encephalitis, and about 400 to 500 people died (Vaccines by... 2016). The measles vaccine has caused a reduction in the spread of measles by

greater than 99% in the United States. But measles still occurs in other countries and people who are not vaccinated and travel to these countries can get the disease and bring it back to the U.S. (Vaccines by... 2016). In recent years, however, there have been large outbreaks of measles. In 2014, 667 cases of measles were reported, in 2015, 188 cases were reported, and in 2016, 70 cases were reported (Measles Cases... 2017). Some of these cases were thought to be caused by a traveler from overseas who brought it back to the United States. Other cases were determined to be caused by unvaccinated communities (Measles Cases... 2017).

Mumps

Mumps is a disease that is also caused by a virus. Its symptoms include the swelling of salivary glands, puffy cheeks, swollen jaw, fever, headache, loss of appetite, fatigue, and aching muscles (Diseases and... 2017). The mumps vaccine is about 88% effective if two doses are received. The vaccination for mumps began in 1967 and since then the cases of mumps has been reduced by 99% in the United States (Vaccines by... 2016). Mumps still does occur, although it is typically in school settings such as high school or college.

Rubella

Rubella is a disease that is also caused by virus and its symptoms include mild fever and rash over the entire body in children. But it can also cause birth defects or miscarriage if a pregnant woman gets infected (Vaccines by... 2016). One dose of the rubella vaccine is about 97% effective. The last epidemic of rubella occurred in 1964-65 and about 12.5 million cases were reported. However, as of 2004, rubella has been eliminated from the United States (Vaccines by... 2016). Rubella still does occur in other countries however and people who are

not vaccinated and travel to these countries can get the disease and bring it back to the U.S (Vaccines by... 2016).

DTap, DT, Td, Tdap

Another example of a combined vaccine is the vaccine that combines the diphtheria, tetanus, and pertussis vaccines. There are four of these vaccines available: DTaP, DT, Td, and Tdap. DTaP and DT are given to younger children who are under 7 years old. Td and Tdap are given to older children and adults (Diseases and... 2017). DTaP stands for diphtheria and tetanus toxoids and acellular pertussis. Children should get five doses of the DTaP or DT vaccine and these doses should occur at ages 2 months, 4 months, 6 months, 15-18 months, and 4-6 years (Diseases and... 2017). The DT vaccine does not contain the pertussis vaccine. Anyone over 6 years old cannot get the DTaP vaccine and can instead get the Td or Tdap vaccine. The Td vaccine is used as a booster vaccine that is given every 10 years or if someone is exposed to tetanus (Diseases and... 2017). One dose of Tdap is given to anyone 11-18 years old and 19 years or older. Pregnant women should also get the Tdap vaccine between 27 and 36 weeks of the pregnancy (Diseases and... 2017).

Diphtheria

Diphtheria is a respiratory disease that is caused by the bacteria *Corynebacterium diphtheria*. The symptoms of diphtheria are sore throat, weakness, fever, and swollen glands. The *Corynebacterium diphtheria* bacteria attaches to the respiratory system and releases a poison that kills the tissue and causes the formation of a thick coating that builds up on the nose or throat. This build up can make it difficult for a person to breathe or swallow (Vaccines by... 2016). The route of transmission of diphtheria is via droplets from coughing or sneezing. In

1921, 206,000 cases of diphtheria were reported and of those there were 15,520 deaths (Vaccines by... 2016). But in the past 10 years there have been fewer than five cases reported in the United States (Vaccines by... 2016). However, it is still a problem around the world.

Tetanus

Tetanus is an infection that is also known by the name lockjaw and is caused by the bacteria *Clostridium tetani*. This bacteria releases a toxin into the body and causes contractions in the muscles (Diseases and... 2017). This symptom of muscle contraction is why Tetanus is called lockjaw because the muscles in the jaw contract and 'lock up'. This makes it difficult for a person to breathe or swallow (Diseases and... 2017). Other symptoms include seizures, muscle spasms, and paralysis (Diseases and... 2017). Tetanus is not an infectious disease that can be spread to other people. The *Clostridium tetani* bacteria can infiltrate the body through a cut on the skin and can be found in soil, dust, or manure (Diseases and... 2017). Tetanus is included in the DTaP vaccine that is given to younger children but the immunity to it decreases as time passes. This means that a booster shot is needed for older children and adults which is given with the Tdap vaccine. The Tdap vaccine contains a full dose of the tetanus vaccine but lower doses of the diphtheria and pertussis vaccines (Diseases and... 2017). It is recommended that a booster is given every 10 years.

Pertussis

Pertussis is a bacterial disease that is also known by the name whooping cough. It is caused by the bacteria *Bordetella pertussis* and is a highly contagious disease (Diseases and... 2017). It is spread by sneezing or coughing near someone who then can breathe the bacteria into their body. The symptoms of pertussis include severe coughing, vomiting, and trouble sleeping.

This symptoms can then lead to other complications such as weight loss, incontinence, fractured ribs, or passing out caused from excessive coughing (Diseases and... 2017). These symptoms will typically appear between 7 and 10 days but could show up as late as 6 weeks (Diseases and... 2017). Pertussis is usually more severe for babies who have not gotten the first vaccine yet. Many babies are hospitalized with pertussis and of those 1 in 4 will get pneumonia, about 1 or 2 in 100 will undergo convulsions, and 1 or 2 in 100 will die from the disease (Diseases and... 2017).

Polio

Polio or poliomyelitis is an infectious disease that is cause by a virus. The virus resides in the throat or in the tract of the intestines and affects the nervous system (Diseases and... 2017). Polio can be spread by contact with secretions from the mouth or nose of an infected person or by coming into contact with the feces of someone who is infected (Diseases and... 2017). As many as 95% of people with polio experience no symptoms but others can have flu-like symptoms, stiff neck or back, or painful limbs. Less than 1% of those with polio with experience permanent paralysis of their limbs and other muscles which can lead to disability or even death (Diseases and... 2017). The polio vaccine consists of two different kinds, one is the inactivated polio vaccine and the other is the oral polio vaccine. The inactivated polio vaccine has been in use in the United States since 2000 (Diseases and... 2017). The vaccine is typically given to children and consists of four doses given at 2 months of age, 4 months, 6 to 18 months, and 4 to 6 years old (Diseases and... 2017). Adults should be given three doses of the vaccine if they did not receive it as a child or if they are traveling to somewhere that has a high risk for polio (Diseases and... 2017). The polio vaccine was first put into use in 1955 when polio was common in the United States. In fact, polio harmed over 35,000 people in the U.S every year (Diseases

and... 2017). Since 1979 the United States has been free from polio, although it still occurs in other places in the world (Diseases and... 2017).

Pneumococcal Disease

Pneumococcal disease is a bacterial disease caused by the *Streptococcus pneumonia* bacteria (Diseases and... 2017). Pneumococcal disease is manifested in different ways, such as pneumonia, bacteremia (blood infection), meningitis (infection of the brain and spinal cord), and otitis media (ear infections) (Diseases and... 2017). The symptoms vary depending on the manifestation of the disease and it is spread by contact with secretions from coughing or sneezing (Diseases and... 2017). The pneumococcal vaccine consists of two kinds, the pneumococcal conjugate vaccine (PCV13) and the pneumococcal polysaccharide vaccine (PPSV23). The numbers in the vaccine indicate how many types of the 90+ types of pneumococcal bacteria the vaccines protects against (Diseases and... 2017). PPSV23 does not include protection against pneumonia while PCV13 does provide protection against it. PCV13 is given as four doses to children at ages 2 months, 4 months, 6 months, and 12 to 15 months (Diseases and... 2017). It is given as one dose to adults who are over 65 years old and who have not received the vaccine. This dose should be followed up by a dose of the PPSV23 one year after (Diseases and... 2017). Some children or adults between 6 and 64 years old who are at an increased risk for a pneumococcal disease should receive one dose of PCV13. One dose of PPSV23 is also recommended for adults who are over 65 years old and any person with a long term health issue (Diseases and... 2017). 88% of pneumococcal disease in children has fallen since the creation of this vaccine (Vaccines by... 2016).

Influenza

One of the most common vaccines known is the influenza or flu vaccine. The flu is caused by the influenza virus and it is spread by close contact to an infected person or by coughing or sneezing (Vaccines by... 2016). The flu usually is prominent in the United States during the months of October to May. Anyone is susceptible to flu, but infants, elderly people, pregnant women, or anyone with a weak immune system are more susceptible. The symptoms include fever, aching muscles, fatigue, cough, headache, and a stuffy or runny nose (Vaccines by... 2016). The flu vaccine can do many things including preventing the flu, preventing the spread of the flu, and weaken the severity of the flu if a person were to still get it. It is recommended that every person get one dose of the vaccine each year during flu season (Vaccines by... 2016). The reason the vaccine is needed every year is because there are a lot of flu viruses and the ones causing the flu each year can change. The vaccines are made so that they protect against three or four of the flu viruses that are thought to cause the flu that year (Vaccines by... 2016). There are two different kinds of the flu vaccine called trivalent and quadrivalent. The trivalent vaccine provides protection against two influenza A viruses and one influenza B virus. This vaccine can be given in different ways, such as the standard dose for those older than 6 months, the high dose for those older than 65 years, the recombinant shot that is free of eggs for those older than 18, and a shot made with adjuvant for those older than 65 (Diseases and... 2017). The quadrivalent vaccine provides protection against two influenza A viruses and two influenza B viruses. This vaccine has two types, the intradermal quadrivalent shot for those between 18 and 64 years old, and the quadrivalent shot for those older than 4 years (Diseases and... 2017). Many people believe they can get the flu from the flu vaccine but this is not true. The vaccines do not contain the flu virus, instead they contain the killed virus or do not contain the virus (Diseases and... 2017).

Vaccine Safety and Autism

Concerns over vaccines are legitimate as it is a parent's responsibility to ensure that their children are and remain healthy. This has led to parents voicing their concerns and potentially not vaccinating their children. While these worries are valid, it is important for parents to educate themselves as much as possible to make a fully informed decision. The concerns exist for a variety of reasons. As reported by the American Academy of pediatrics,

“...44% of parents reported concern over pain associated with receiving multiple injections during a single visit, 34% expressed unease about receiving too many vaccines at a single visit, 26% worried about the development of autism or other potential learning difficulties after receiving vaccines, 13.5% expressed concern that vaccines could lead to chronic illnesses, and 13.2% stated that vaccines were not tested enough for safety before their use” (Edwards K and Hackell J 2016).

But vaccines are made for a specific reason, to provide protection to children and others and prevent harmful diseases from becoming prevalent. Since vaccines are a source of protection and prevention against illness it would not make sense for them to cause more or other harmful side effects. This is a serious business and the safety of vaccines are taken seriously as well. According to a clinical report from the American Academy of Pediatrics,

“The current system for developing, testing, and regulating vaccines requires that the vaccines demonstrate both safety and efficacy before licensure and that long-term safety is monitored” (Edwards K and Hackell J 2016).

There are many safety measures in place for vaccines from when they are being produced to even after they are on the market. Ingredients in vaccines are tested for many qualities such as purity, potency, sterility, consistency, activity, and stability (Di Pasquale et al 2016). The ingredients have to be the highest purity and their origins must be able to be traced (Di Pasquale et al 2016). Once a license is gained for a vaccine, it must still undergo quality control tests, non-clinical tests, toxicity tests, and safety tests (Di Pasquale et al 2016). The sites where the vaccines are produced are also inspected and approved before production begins, along with inspections happening regularly after production begins (Di Pasquale et al 2016). When applying for a license, a Risk Management Plan is produced. In this plan risks are named and plans on how to deal with these risks are given (Di Pasquale et al 2016). After a license is gained one method of safety still in place is passive surveillance in which the public or healthcare providers report any adverse effects following immunization (AEFIs) (Di Pasquale et al 2016).

Despite all that goes into making vaccines safe, there are many myths and controversies surrounding vaccines that keep parents from having their children vaccinated. Some simply believe that vaccines are not needed (Edwards K and Hackell J 2016). In a survey conducted by the American Academy of Pediatrics in 2006 showed that 75% of pediatricians had a parent that refused a vaccine and in 2013 this number had increased to 87% (Edwards K and Hackell J 2016). Between 2006 and 2013 there was also an increase in parents rejecting one or more vaccines with this number increasing from 9.1% to 16.7% (Edwards K and Hackell J 2016). However, one of the biggest myths surrounding vaccinations is the idea that vaccinations can cause autism.

Since the publication of an article (that has since been retracted) relating the MMR vaccine to intestinal disorders and autism many parents have had more concerns over vaccinating

their children. Many studies conducted since have shown that there is no link between the MMR vaccine and autism. A study published in 1999 was conducted in the United Kingdom and used data on children diagnosed with an autism disorder from eight North Thames health districts (Taylor et al 1999). It was found that the cases of autism did increase each year steadily but there was not a major change when the MMR vaccine was introduced (Edwards K and Hackell J 2016). Therefore it was concluded that there is not a causal link between the MMR vaccine and autism. However, the study points out how there is not much data on the occurrence of children with autism before and after the MMR vaccine was first in use in the United Kingdom (1988) (Taylor et al 1999). The study also suggested that the original reasoning for the link between MMR and autism is the fact that the vaccine is given around the same time that most parents notice symptoms of autism in their children (Taylor et al 1999). Therefore, this correlation would be expected but it has not been proven.

A study conducted in Denmark to determine if there is a link between the MMR vaccine and autism was published in 2002. This study was a retrospective study on children born in Denmark from January 1991 through December 1998. They found that 82% of the children had received the MMR vaccine and of that 82% (440,655), 316 children had been diagnosed with autism and 422 had been diagnosed with an autism-spectrum disorder (Madsen et al 2002). The study also commented on how MMR vaccine use appeared to occur at the same time there was an increase in autism diagnosis. However, they found that this was not the case in Denmark (Madsen et al 2002). It was also found that there was a similar incidence for autism in both children vaccinated and unvaccinated (Madsen et al 2002). The study concluded that based on their evidence there was no link found between the MMR vaccine and the development of autism.

Vaccines are Important

Everyone in the world experiences an illness at some point in their lives. This could just be a cold or a more serious disease. Most people can easily get over a cold but it's not as easy to get over a serious disease. This is where the benefits of vaccines can be seen. A vaccine works to prevent and protect an individual from getting a disease in the first place. Since the invention of the vaccine by Edward Jenner in 1796, vaccine's benefits to society have been clear. The vaccine for smallpox has allowed the disease to become eradicated from the world. Other vaccines have led to reduced cases of many diseases that would otherwise cause much illness. Vaccines have been invented for many common diseases in the world, such as the flu, measles, mumps, rubella, and more. Having concerns about vaccines and the risks associated with them is understandable. But it is important to be educated about them, not just about the risks but also about the abundant benefits. It is important that children and adults are vaccinated for the many diseases with a vaccine because they are not eradicated diseases. They might not be a problem now but if people continue to not vaccinate their children then these diseases can become a huge problem. The article *Vaccine impact: Benefits for human health* said it best,

“Once a well-known and much-feared disease appears to have disappeared, individuals, including healthcare professionals, no longer view ongoing prevention with the same sense of urgency. Reduced coverage is inevitably associated with resurgence in disease, with outbreaks potentially leading to significant morbidity and loss of life. Ensuring the continued success of immunisation programmes is the responsibility of all: individuals, healthcare professionals, government and industry,” (Doherty et al 2016).

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